Cryptogamic Insects (Fungi)
Dutch Elm Disease

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DUTCH ELM DISEASE

The first tree in Quebec known to have Dutch elm disease. Discovered in August, 1944, at St. Ours.

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DUTCH ELM DISEASE

HISTORY AND DISTRIBUTION

This destructive disease of elm was first observed in The Netherlands in 1918. Although the origin of the fungus that causes the disease is obscure, it was probably brought from Asia during the First World War. The disease spread rapidly and now occurs throughout the whole of Western Europe. In 1930 it was found in Ohio in the United States, having been introduced in elm burl logs imported for the manufacture of veneer. Since then it has spread throughout north-central and northeastern United States. Incipient infections in that country centered around ports of entry, rairoad distributing yards, and veneer plants.

The disease was not discovered in Canada until 1944, when it was found near Sorel, Quebec (front cover). Judging from the size of the infected area, the disease had been present for a considerable period of time before being recognized. Indications are that is was brought to Quebec directly from Europe rather than from the United States. Since 1944, the infection has spread over a large area in the valleys of the St. Lawrence and Ottawa Rivers, through 47 counties in central and southwestern Quebec and 11 counties in eastern Ontario, from the City of Quebec to Kingston and Ottawa in Ontario. In southwestern Ontario, a second extensive occurrence of the disease has been recorded in 18 counties since 1950. Here, the disease, together with the European vector, has apparently spread into Canada from the United States. In this part of the Province the most severe infection has been found in Essex County, where in Windsor and vicinity hundreds of diseased trees have been located.

It should be pointed out that, while it is convenient to give the distribution of the disease by counties, in many instances, particularly in Ontario, only one or two diseased trees have been found in a given county. This is not true of Quebec where the disease has been present for a longer time and where there is heavy infection in many counties. On the other hand, as there has been no organized survey for Dutch elm disease carried out since 1951, it may well be more widely distributed than present knowledge indicates.

For some years past a limited amount of scouting has been carried out in the Maritime Provinces and in Manitoba with negative results. However, in November 1957, the causal fungus of Dutch elm disease was obtained in culture from bark collected from a single elm tree in Woodstock, New Brunswick. It is not known how it may have been introduced. The nearest known cases of the disease are about 55 miles away in the State of Maine. Arrangements were immediately made to have the infected tree, which was practically dead, taken down and treated to prevent the emergence of beetles carrying spores, but at that time of year it was not practicable to undertake survey work in the vicinity to determine if there were other infected trees. This will be done as early as possible in 1958.

HOSTS

All species of American and European elms are hosts for Dutch elm disease, although a wide variation occurs in the degree of their susceptibility. While no American elm resistant to the disease has been found, there are several European

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strains, notably the Buisman and the Bea Schwarz elms, that are relatively resistant. These have been imported to North America and released to nurserymen for propagation. Asiatic elm species, Chinese and Siberian, are generally resistant.

SYMPTOMS

The first external symptoms of this disease are a rapid wilting of the leaves on one or more limbs in the upper crown (Fig. 1) and a discoloration of the leaves on the affected branches to brown or yellow. These leaves then become shrivelled and brittle and are usually shed prematurely. Sometimes the tips of the affected branches assume a downward, hook-like curve which has been called

Fig. 1—An early stage of the disease.

"shepherd's crook". When the leaves have fallen from the tree this is a diagnostic aid. Wilting and discoloration of the leaves usually appear first about mid-June and are most evident during July and August. Internally, diseased branches or stems in cross-section show a more or less continuous brown ring in the outer sapwood. In longitudinal section this discoloration appears as long, discontinuous streaks (Fig. 2). The symptoms of Dutch elm disease, both internal and external, are so similar to those of two other native diseases

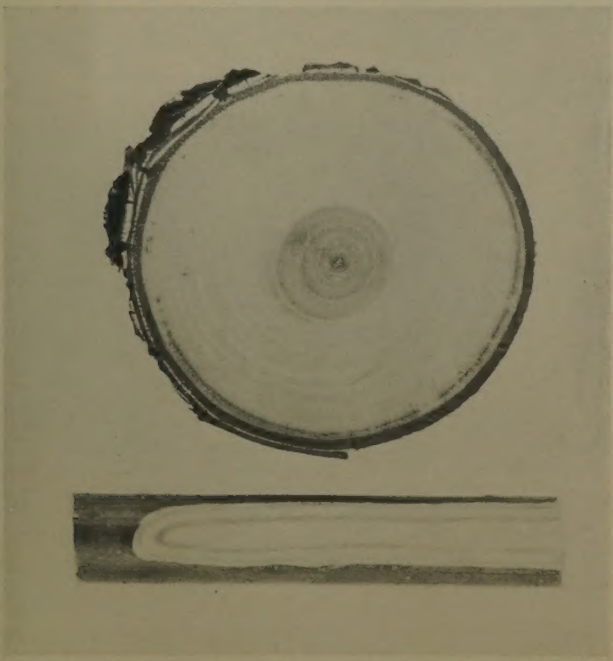

Fig. 2—Diseased elm branch in cross and longitudinal sections, showing the brown ring and the streaks.

of elm, namely Verticillium wilt and Cephalosporium wilt, that identification in the field is not possible with certainty. It is necessary, therefore, to collect specimens of affected branches and to culture them in the laboratory. The cultural characteristics of the three fungi concerned are sufficiently distinct to make identification simple.

Both large and small trees can be killed by Dutch elm disease. Small trees may die in a single season but in large trees the disease usually progresses more slowly and such trees may survive for a number of years. At times, however, even large trees may be killed rapidly, and, in any event, a tree is disfigured once it becomes infected.

CAUSE

Dutch elm disease is caused by the fungus *Ceratocystis ulmi* (Buism.) C. Moreau. As a parasite it develops in the water-conducting vessels of the sapwood where it produces spores and a poison which are carried in the sap stream

to distant parts of the tree. The toxin causes the death of branches with subsequent wilting and discoloration of the leaves. In addition to the toxic effect it is probable that the growth of the fungus itself results in a partial stoppage of the vessels, thus contributing to wilt of the leaves. After the death of the host tissue the fungus continues to grow as a saprophyte, producing another type of spore on the inner surface of the bark, on the outer surface of the wood, and in insect galleries in the bark or wood.

CARRIERS OF THE DISEASE

The spread of the Dutch elm disease fungus from infected to healthy elm trees is dependent almost entirely on insects. The spores that are borne in insect galleries are sticky and so are not disseminated by air currents as is usually the case with fungus spores. Instead, they adhere to the bodies of emerging adult beetles and are introduced into other elm trees when the beetles enter the bark to feed or to establish brood tunnels. In Canada and the United States, the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.) and the smaller European elm bark beetle, *Scolytus multistriatus* (Marsh.) are responsible for the spread of the causal fungus.

The smaller European elm bark beetle was introduced from Europe into the United States prior to 1904, when it was discovered near Boston, Mass. It was first recorded in Canada in 1948, in southwestern Ontario in the vicinity of Windsor. Since then it has spread rapidly eastward and is now well established in the Toronto area. In 1957 it was found as far east as Port Hope in Durham County. As far as is known, it does not occur elsewhere in Canada. The native elm bark beetle is found throughout the range of elm in North America, and is the only vector of Dutch elm disease in eastern Ontario and the Province of Quebec. However, the smaller European elm bark beetle is the more aggressive species and once it invades an area crowds out the native elm bark beetle to become the principal vector. At present it is not known how far eastward and northward the range of the European species will extend. The present indications are that it may become the principal agent in the spread of the disease in Ontario.

The native elm bark beetle and the European elm bark beetle confine their feeding and breeding to all species of elm. Feeding by the adults takes place on living elms, while elm material, such as rapidly dying trees, storm-broken limbs, firewood, or recently cut elm wood is selected for breeding. They will not deposit eggs in elm material without bark, or with bark separating from the sapwood.

The adults of both species are about $\frac{1}{8}$ inch long and range in color from brown to black. The smaller European elm bark beetle (Fig. 6) can be distinguished from the native elm bark beetle (Fig. 3) by its shiny surface and the posterior, ventral side of the abdomen being concave with a tubercle or blunt spur extending backward from the center of the second ventral abdominal segment. The larvae of both species are similar in appearance, being white, wrinkled, legless grubs with brown heads. The native elm bark beetle overwinters in both the adult and larval stages within the bark galleries while the smaller European elm bark beetle passes the winter in the larval stage. Both species have about two generations a year. The adult beetles upon completing their development in the brood material, emerge and fly to the nearest healthy elm trees to feed in the bark. Bark feeding by the European species takes place in the crotches of the small twigs (Fig. 8) usually near the periphery of the crown. The native elm bark beetle feeds in the bark of the trunk and larger branches (Fig. 5). After feeding in the bark of healthy elms, the beetles fly to brood material where they construct their egg galleries. The galleries are formed in the inner bark, slightly grooving the surface of the wood.

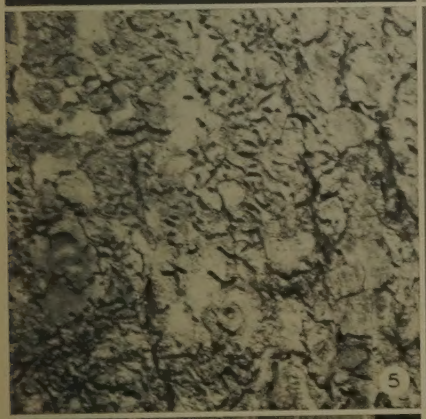

Fig. 3—Adult of the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.) × (18)
Fig. 4—Tunnels of the adult and larval galleries of the native elm bark beetle on the inner bark surface of elm. about × 0.6
Fig. 5—Feeding scars made by the adults of the native elm bark beetle on the bark of healthy elm. about × 0.6
Fig. 6—Adult of the smaller European elm bark beetle *Scolytus multistriatus* (Marsh.). × (19)
Fig. 7—Tunnel of the adult and larval galleries of the smaller European elm bark beetle on the inner bark surface of elm. about × 0.6
Fig. 8—Adult of the smaller European elm bark beetle feeding, and feeding scars in the twig crotches of healthy elm. about × 1.5

The native elm bark beetle usually cuts two diverging galleries across the grain of the wood from the point of entry to form a wide "V" (Fig. 4). The European bark beetle cuts a single egg gallery along the grain of the wood (Fig. 7). The eggs of both species are deposited in niches cut in opposite sides of the galleries. The larvae feed in the inner bark and on the surface of the wood, making mines at right angles to the egg galleries. When fully grown, the larva constructs a cell at the end of the mine, pupates, and the adult emerges by cutting a hole through the bark to the outside.

When constructing their brood galleries adults carrying spores of the causal fungus can establish the fungus as a saprophyte within the galleries. As the spores produced by the saprophytic form are sticky, they are brought out on the bodies of the adults of the next generation and introduced into healthy elms when they feed, or into other breeding places. However, successful inoculation of living elm depends upon the spores entering the long, functioning conducting vessels of the spring and early summer wood. During this period these vessels are close to the surface of the wood and the spores may be introduced when the adults are feeding. The vascular system produced after midsummer consists of much shorter and relatively compressed conducting vessels at the wood surface that restrict spore movement. Inoculation at this time usually results in a very localized and temporary infection. The twig crotches formed during the current year seldom contain the long conducting vessels found in older twigs. Late feeding by the adults rarely results in extensive infection as occurs in the case of early feeding on the older twigs.

In addition to the transmission of the causal fungus by bark beetles, it may occasionally be transferred from one tree to another by means of root grafting. This, of course, can occur only when the roots of diseased trees make contact with the roots of healthy trees.

METHODS OF CONTROL

It should be pointed out that even the most carefully devised program will not give complete control of Dutch elm disease. However, experience in the United States has shown that in a given area losses can be limited to 1 to 2 per cent a year. If no control measures are adopted, the loss of a considerable proportion of the elm population may be expected. However, it is now evident that this disease cannot compare in virulence with the blight that destroyed chestnut as a commercial species in North America.

Once a tree has become infected there is practically no hope of saving it by pruning the diseased branches or by any other method known at present. It therefore becomes necessary to use indirect measures. The role of the two species of bark beetles in the transmission of the causal fungus of Dutch elm disease suggests two ways by which injury can be prevented or reduced. The first of these prevents or greatly lessens feeding by beetles during the critical spring and early summer period by means of spraying; the second reduces the bark beetle population by destroying elm material suitable for breeding, that is, by sanitation.

Where the disease is already present both methods should be used for efficient control, as one complements the other. Where the disease is not yet present but its occurrence is anticipated, spraying is not recommended but sanitation should be underaken. This requires no specialized equipment and is less costly than spraying. A thorough sanitation program will greatly decrease the seriousness of the disease should it later reach a given community.

The two methods will now be considered in detail.

Spraying

Bark feeding by the beetles can be prevented by spraying the trees with DDT in the form of an emulsion. Spraying may be done at any time of the year that the trees are dormant—before the leaves emerge in the spring or after they are shed in the fall. However, spraying should not be done when the temperature is less than 40°F. A single, thorough application is sufficient; this leaves on the bark surfaces a deposit of DDT that is lethal to the adult beetles when they attempt to feed during the growing season. For spraying to be fully effective it is obvious that all bark surfaces of the trunk, branches, and twigs must be completely covered. The lethal properties of the DDT deposit on the bark surfaces deteriorate slowly but this loss is sufficient to make necessary an annual spray program. However, each additional spray adds considerably to previous deposits. It is not always possible or practical to spray all the healthy elm trees over a very wide area; treatment of trees within a radius of 500 feet of known diseased trees should be undertaken.

The sprays must be applied by either a hydraulic sprayer or a mist blower. Mist blowers use low volumes of concentrate sprays; hydraulic sprayers require large volumes of dilute sprays. Usually 25 gallons of spray are necessary to treat a 50-foot elm tree by a hydraulic sprayer, compared with 2 gallons by a mist blower. The high volume of spray necessary with a hydraulic sprayer is frequently objectionable in cities and towns because of excessive run-off and contamination of public and private properties. As far as possible, the collection of run-off spray in puddles should be avoided, as this creates a serious hazard to birds and animals. Streets, sidewalks, and lawns heavily contaminated by spray should be flushed with water as soon as possible after spraying.

The following spray formulae are recommended:

Hydraulic Sprayer

DDT, technical grade	20 pounds
Xylene (solvent)	4 gallons
Triton X-100 (emulsifier)	1 pint
Water—to make	100 gallons

OR

8 gallons of commercially prepared 25% DDT emulsifiable concentrate to water to make 100 gallons of spray.

Mist Blower

DDT, technical grade	46½ pounds
Xylene	9 gallons
Triton X-100	2½ pints
Water—to make	40 gallons

OR

20 gallons of commercially prepared 25% DDT emulsifiable concentrate to water to make 40 gallons of spray.

Some commercial DDT emulsions contain solvents that may cause bud and twig injury at the relatively high concentrations required. Xylene type solvents are safe and assure maximum deposit of DDT on the bark surfaces. DDT emulsion sprays dry quickly and are not affected by rains one or two hours after application. When handling DDT concentrates, it should be noted that xylene has a rather low flash point and the vapors are easily ignited. The fumes of xylene are poisonous and will cause headaches, nausea, and irritations of the eyes, nose, and mouth. Care should be exercised when spraying to avoid contamination of vegetation likely to be consumed by humans or domestic animals, and receptables where birds or other forms of wildlife might come to drink. Contamination of streams with the spray, which might poison fish and fish-food organisms, should be avoided.

Sanitation

Briefly, sanitation as a measure for the control of Dutch elm disease involves the destruction or treatment of material in which bark beetles might breed and which is close to healthy elms. Freshly cut logs and firewood, dying and recently dead trees, broken branches and stumps of trees recently felled provide ideal material to support heavy bark beetle populations. It is much more important to destroy this type of material than it is to remove trees that are in the early stage of the disease; the latter do not become a hazard to healthy elms until enough wood is killed to permit beetles to breed and emerge carrying fungus spores. All such material should be burned, or debarked and the bark burned, or sprayed with DDT before the adult beetles emerge.

Wood that accumulates during the winter should be treated before May 1 and wood that is cut between that date and August 1 should be treated immediately. A 1 per cent DDT solution made by dissolving 1 pound of DDT in 10 gallons of No. 2 fuel oil or 3 pints of 25 per cent emulsion concentrate in 10 gallons of fuel oil or water, and sprayed thoroughly over all the bark surfaces will kill any bark beetles entering to deposit eggs or emerging from infested material. This spray will injure living trees and other vegetation; care should be exercised in its use. Elm material containing bark beetles should be treated before removal to other places for disposal, otherwise any beetles emerging will be scattered en route, perhaps over a large area. All such material within 500 feet of healthy elms should be treated in one of the ways described.

Actually, sanitation is merely a part of good tree maintenance and the results obtained vary with the degree of care with which the work is done. It is evident that those municipalities which systematically practise tree maintenance will be in a much better position to combat the disease than those which do not. This work can be carried out at any time of the year, but it is most important that as much breeding material as possible should be disposed of before May 1 and that as little as possible should be available to the beetles between May 1 and August 1. The reason for this, as already mentioned, is that it is at this time of year that feeding beetles may introduce the fungus spores into the long conducting vessels of the spring and early summer wood in healthy elms and thus cause infection.

RESPONSIBILITY FOR CONTROL

This Department assumes the following responsibilities in regard to Dutch elm disease: (1) to carry on surveys to determine where the disease occurs, (2) to inform the public of the known distribution and seriousness of the disease and to give information and advice about control measures, (3) to provide laboratory services for the culture and diagnosis of specimens suspected of having Dutch elm disease, (4) to carry on research upon the causal fungus and its insect carriers and on disease resistance in elm, and (5) to establish and enforce regulations prohibiting the importation of elm into Canada and the movement of elm from infected to non-infected areas within this country.

From this it is apparent that the Department does not assume responsibility for the application of control measures. The owners of elm trees, whether they are individuals, towns or cities, counties, or provincial governments have this responsibility. It is difficult for an individual owner to undertake control measures. He may practise sanitation but if his neighbors do not then his work is of no value. The average owner has, of course, neither the equipment nor the knowledge necessary to spray trees, although he can arrange to have this

done by tree companies where these exist. In practice in the United States, where control work has been carried on for a number of years, the responsibility for control is assumed by the municipality with the cost of treatment of trees on private property being borne by the owners in some cases.

Regarding control costs it should be pointed out that once the disease has reached a town or city infected trees will soon die. These then become a hazard to life and property and it becomes necessary to spend money to remove them. Removal of trees from a city street is generally a costly undertaking because it is necessary to take such trees down in sections to avoid injury to electric wiring, buildings, vehicles, and the public. Depending upon circumstances, the cost of removing a single large elm may well exceed $100. Although control measures may also involve considerable costs each year, it has been the experience, both in the United States and Canada, that they are more economical than removing trees. In addition, adoption of control measures preserves the aesthetic and real estate values of trees which, although they cannot be determined exactly, are nevertheless real and substantial.

COLLECTION OF SAMPLES

If an owner suspects that one or more of his elm trees have Dutch elm disease samples should be collected and submitted for culturing and diagnosis. In New Brunswick send samples to the Forest Biology Laboratory, College Hill, Fredericton; in Quebec to the Forest Biology Laboratory, Forestry School, Laval University, Quebec; and in Ontario to the Forest Pathology Laboratory, Southern Research Station, R.R. No. 2, Maple.

Take samples from elm branches that have wilted leaves and show a more or less continuous brown ring in cross-section or long discontinuous brown streaks in longitudinal section in the outer sapwood just beneath the bark (Fig. 2). Several samples from ½ to 1 inch in diameter and from 6 to 7 inches long should be taken, preferably from more than one branch. Wrap the samples in waxed paper to prevent drying and send them to the laboratory for culturing with as little delay as possible. A second type of specimen may be collected. From dead or partly dead trees infested by bark beetles take sections of bark about 2 inches square having one or more insect galleries. About six such squares should be collected from each tree.

The collection of suitable specimens from trees suspected of having Dutch elm disease requires a certain amount of experience and, in the case of branches from large trees, some specialized equipment. *However, it is only a waste of time to collect specimens that do not conform to the above descriptions.* For all trees from which collections are made the following information should be included with the specimens submitted for culturing: owner, address, exact location of tree, date of collection. This information is necessary because when it is determined that a particular tree is diseased it must be re-located, taken down, and the wood treated. Similarly, if the cultures prepared from a dead or dying tree are positive, the infected tree must be treated and also any neighboring healthy elms.

GENERAL

Owners of elm trees in New Brunswick who wish to obtain further information about Dutch elm disease should get in touch with the Forest Biology Laboratory, College Hill, Fredericton, or the District Plant Inspection Office, Saint John, and in Quebec with the Forest Biology Laboratory, Forestry School, Laval University, Quebec, or the District Plant Inspection Office, Canada

Department of Agriculture, either in Quebec or Montreal. Residents of Ontario may use the services of the Forest Pathology Laboratory, Southern Research Station, R.R. No. 2, Maple or the District Plant Inspection Office, Canada Department of Agriculture, in Windsor, London, Guelph, Toronto, or Niagara Falls; the Division of Forest Protection, Department of Lands and Forests, Parliament Buildings, Toronto, or the District Foresters at Aylmer, Hespeler, Maple, Lindsay, Tweed, Kemptville, Parry Sound, North Bay, or Pembroke; or the Provincial Entomologist, Ontario Agricultural College, Guelph. A resident of any province may write to the Forest Biology Division or to the Plant Protection Division, Canada Department of Agriculture, Ottawa, Ontario.

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DUTCH ELM DISEASE

EDMOND CLOUTIER, C.M.G., O.A., D.S.P., Queen's Printer and Controller of Stationery, Ottawa, 1958